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ISDE International Lectures

The 4th ISDE International Lectures

Local Earth Observation Data Cubes for the Digital Earth Vision

May 23, 2023

The Austrian semantic Earth observation data cube - Sen2Cube.at

A research idea becomes a national-wide data cube implementation

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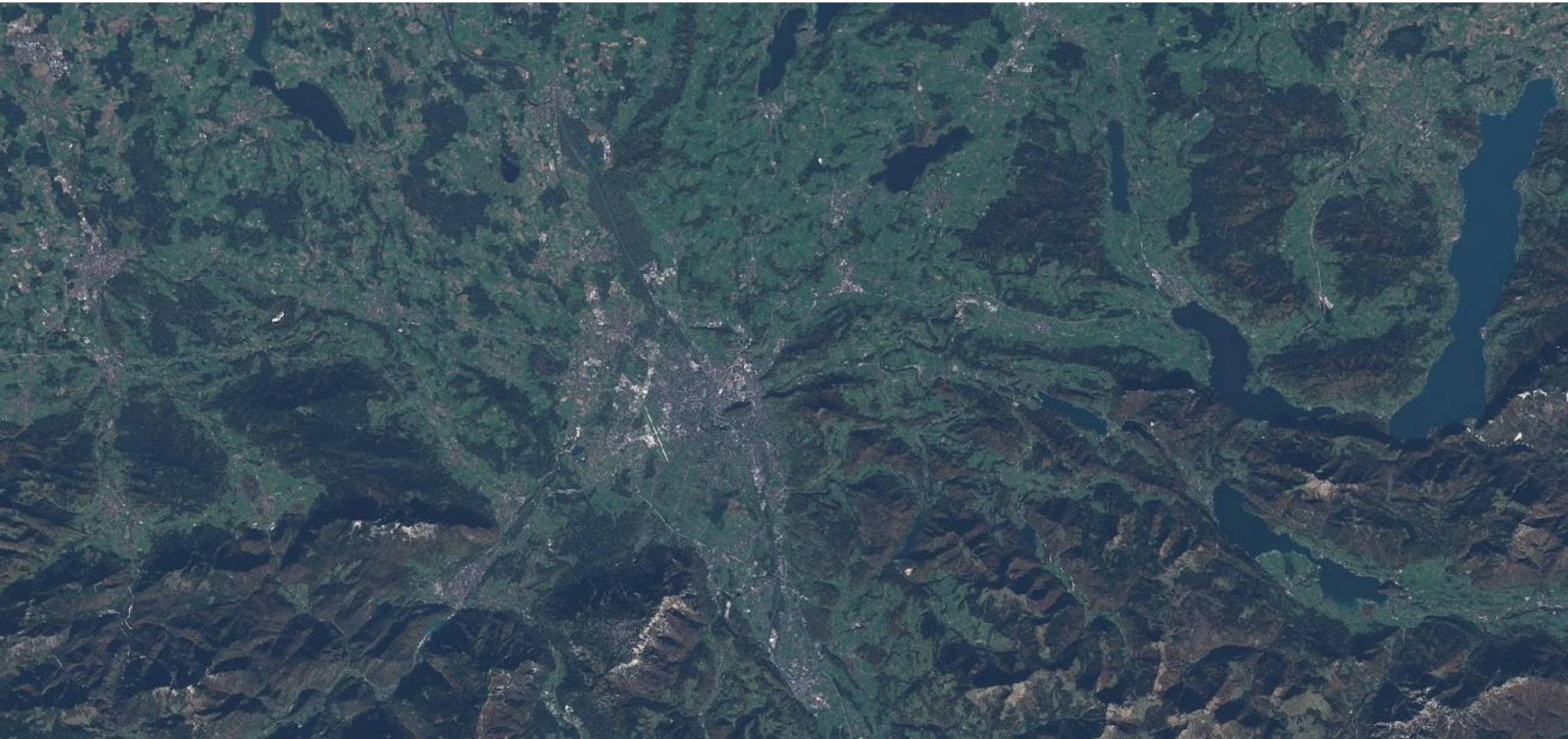
PARIS LODRON UNIVERSITY SALZBURG | Z_GIS

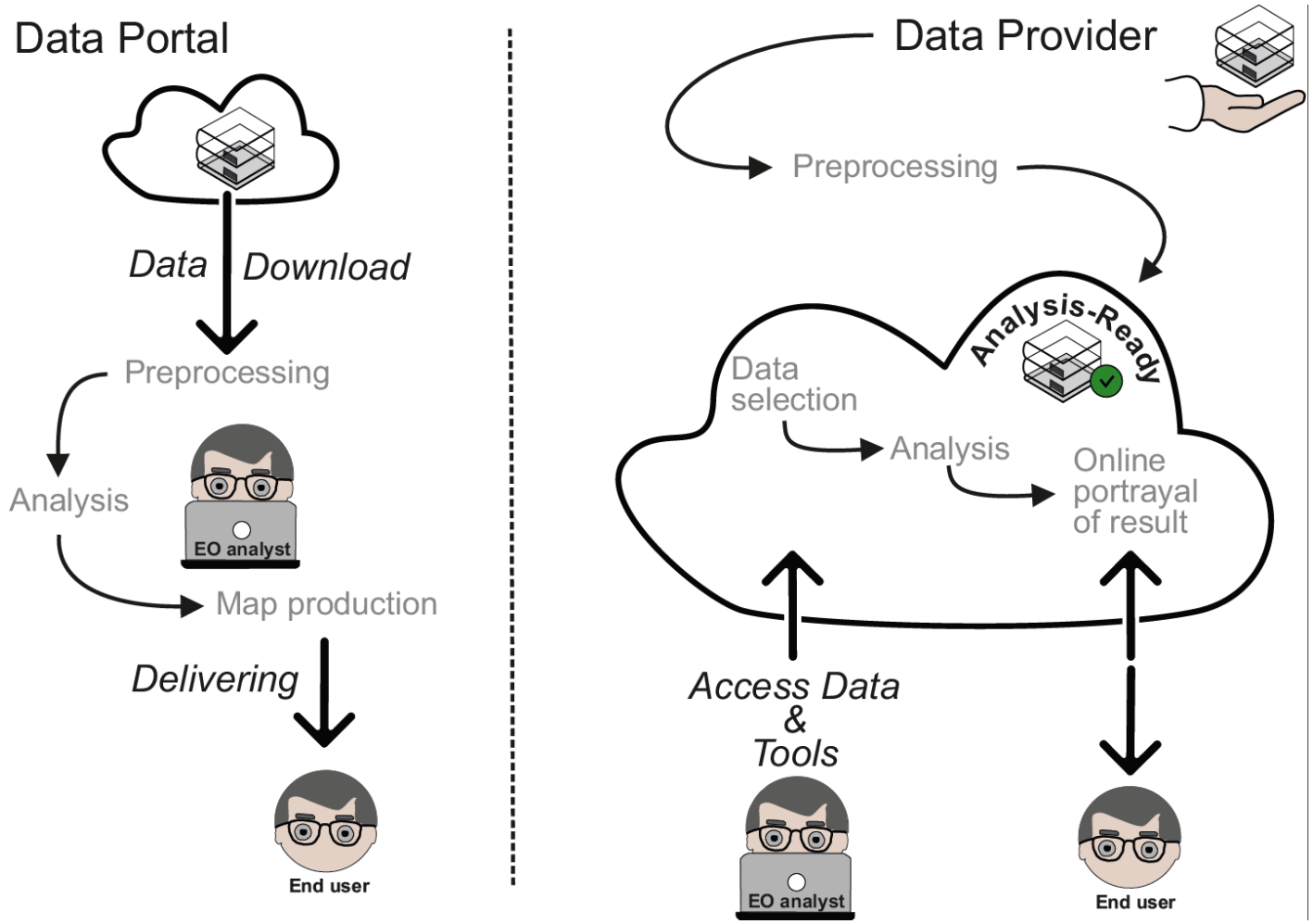
spatial services

WHERE GEOINFORMATION MEETS TECHNOLOGY

Motivation: Big EO Data



Changes in workflows



From: Sudmanns, M., Tiede, D., Lang, S., Bergstedt, H., Trost, G., Augustin, H., Baraldi, A., Blaschke, T., 2019. Big Earth data: disruptive changes in Earth observation data management and analysis? Int. J. Digit. Earth 0, 1–19. https://doi.org/10.1080/17538947.2019.1585976

Big EO Data Analysis Platforms

- **Big EO data analysis platforms: Often provided by large companies** or large research institutions, including collections of PBs of open access data
- **Ease of use of pre-configured platforms**, with no need to consider difficult data structures, software and hardware requirements
- **BUT:**
  - The **dependency on a specific platform**, its data and functionalities, and generally the loss of control **may limit the diversity of users, limiting R&D and the sustainability of business models**
  - We argue for the **additional possibility of 'local' solutions** to use and contribute to big EO data analytics, enable new (different) analyses and product development, otherwise not possible with large-scale systems

Sudmanns, M., Augustin, H., Killough, B., Giuliani, G., Tiede, D., Leith, A., Yuan, F., Lewis, A., 2022. Think global, cube local: an Earth Observation Data Cube's contribution to the Digital Earth vision. Big Earth Data 00, 1–29. https://doi.org/10.1080/20964471.2022.2099236

Our approach

Our approach….

- Make Earth observation (EO) data **easier accessible** & allow **cloud-based analyses** of TBs of data **(if possible programming free)**
- Designing/creating and upscaling our **own developed analysis approach for big EO data: semantic EO data cubes**
- Tackle **new research topics that require big data processing** e.g., around SDGs
- Requirements:
  - Access to computing, storage and big EO data resources and the data management (**at least in proof-of-concept size**).
  - Flexible/adaptable software
  - Own developments on top

➔ Possibility **to create our own cloud service** for big EO data analysis

... implemented by a small team(5 + students)

Definition of a semantic EO data cube

- *”A semantic EO data cube or a semantics-enabled EO data cube is a data cube, where for each observation at least one nominal (i.e., categorical) interpretation is available and can be queried in the same instance”*
- Different data cube software possible; here: Open Data Cube

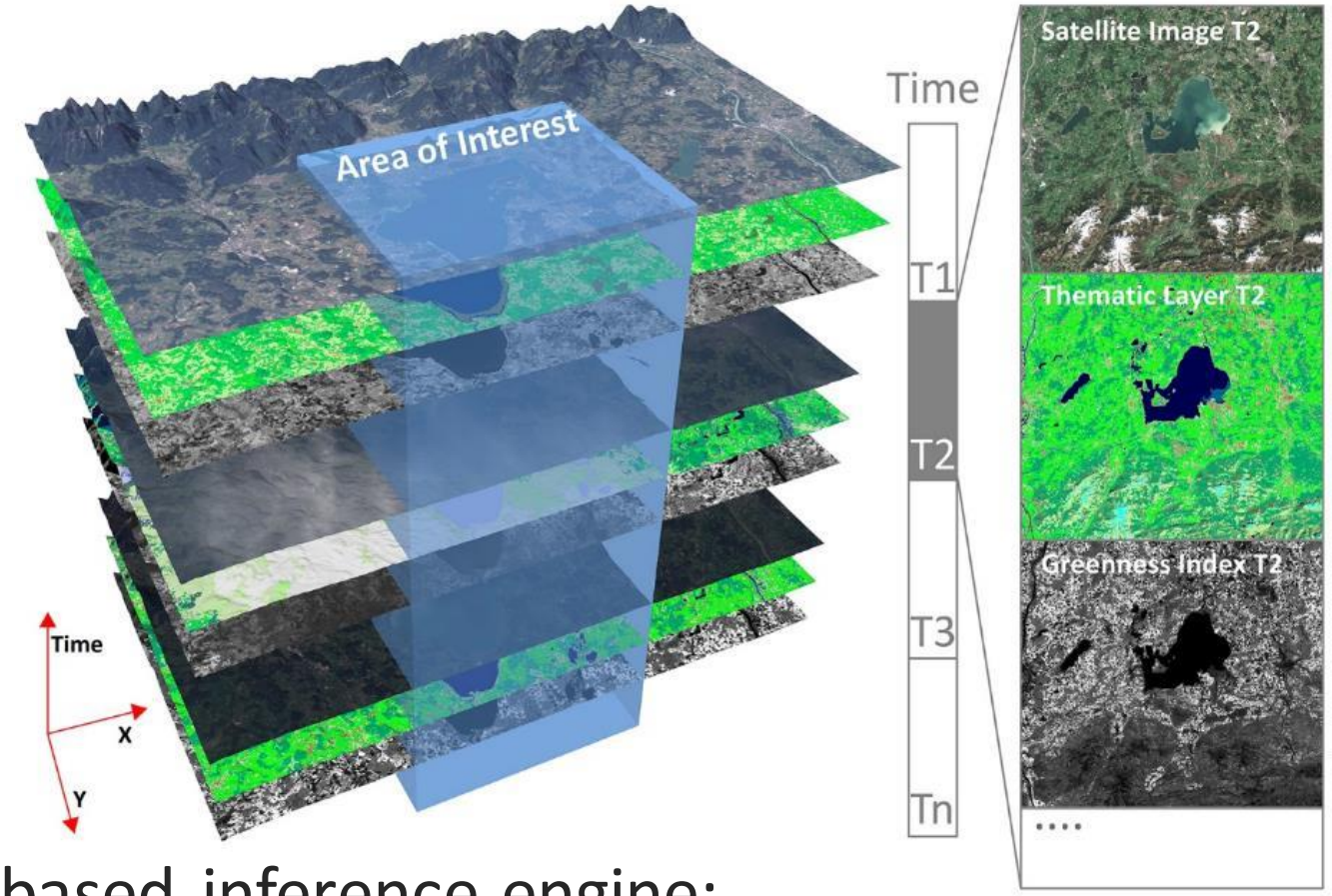
Temporally stacked EO images (+other geodata), either as **view** or as **physical data structure**. Usually coupled with **analysis-ready data (ARD)**. Main goal: Abstracting data storage from users

We go beyond **ARD – starting from semantically enriched data allows programming free access, and an even higher abstraction of data storage from user access**

Augustin, H., Sudmanns, M., Tiede, D., Lang, S., Baraldi, A., 2019. Semantic Earth Observation Data Cubes. Data 4, 102. https://doi.org/10.3390/data4030102

Key components of a semantic EO data cube

2 Data cube technology: **User-defined areas-of-interests and time intervals**



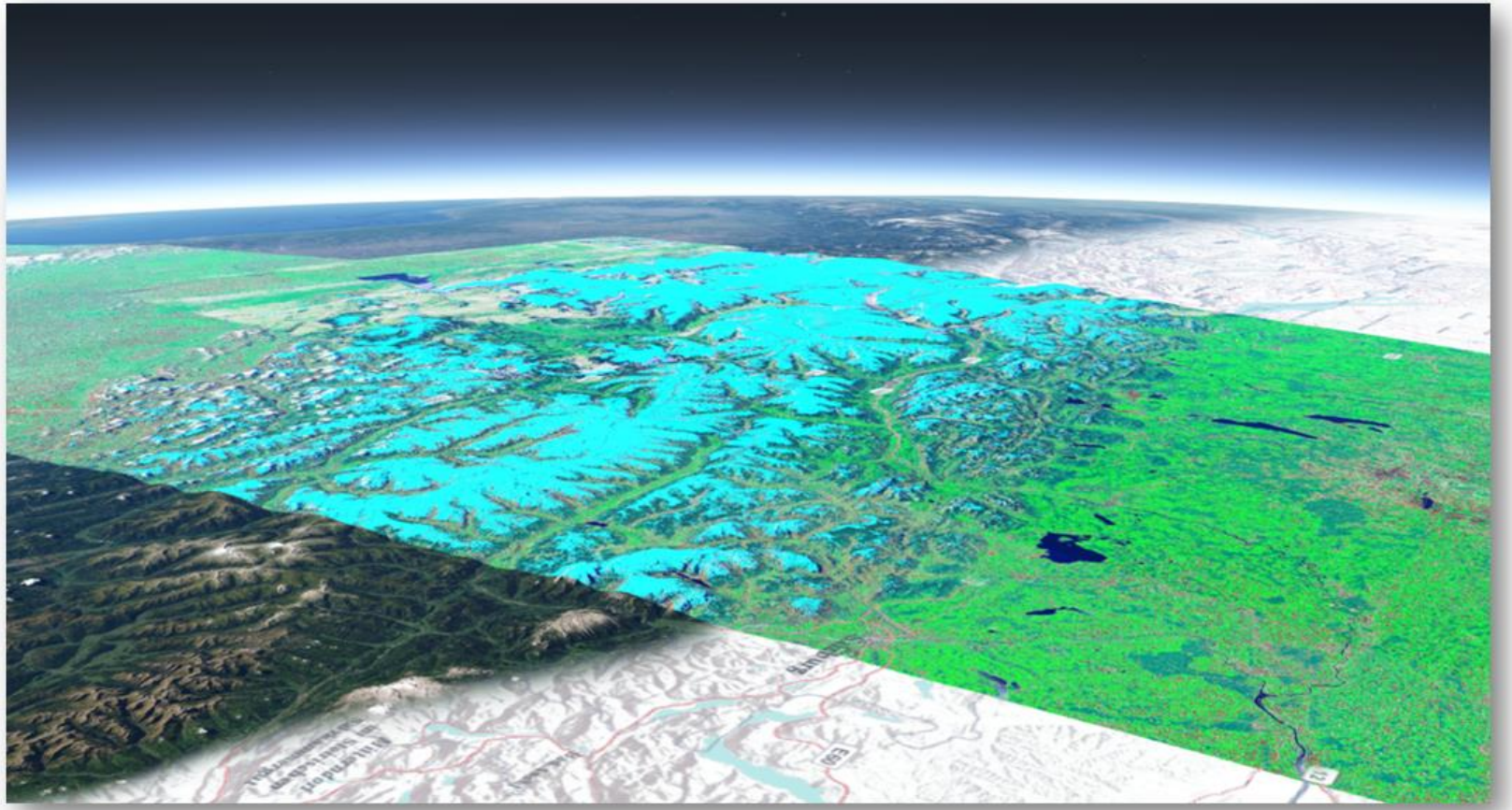
1 Images: All images (here: Sentinel-2), **every pixel semantically enriched** (fully automated, no training samples)

\+ additional (open) datasets (e.g. DEM)

3 Web-based inference engine: **High-level semantic querying**

Tiede, Dirk; Baraldi, Andrea; Sudmanns, Martin; Belgiu, Mariana; Lang, Stefan (2017): Architecture and prototypical implementation of a semantic querying system for big Earth observation image bases. In European journal of remote sensing 50 (1), pp. 452–463. DOI: 10.1080/22797254.2017.1357432

1 Semantic enrichment



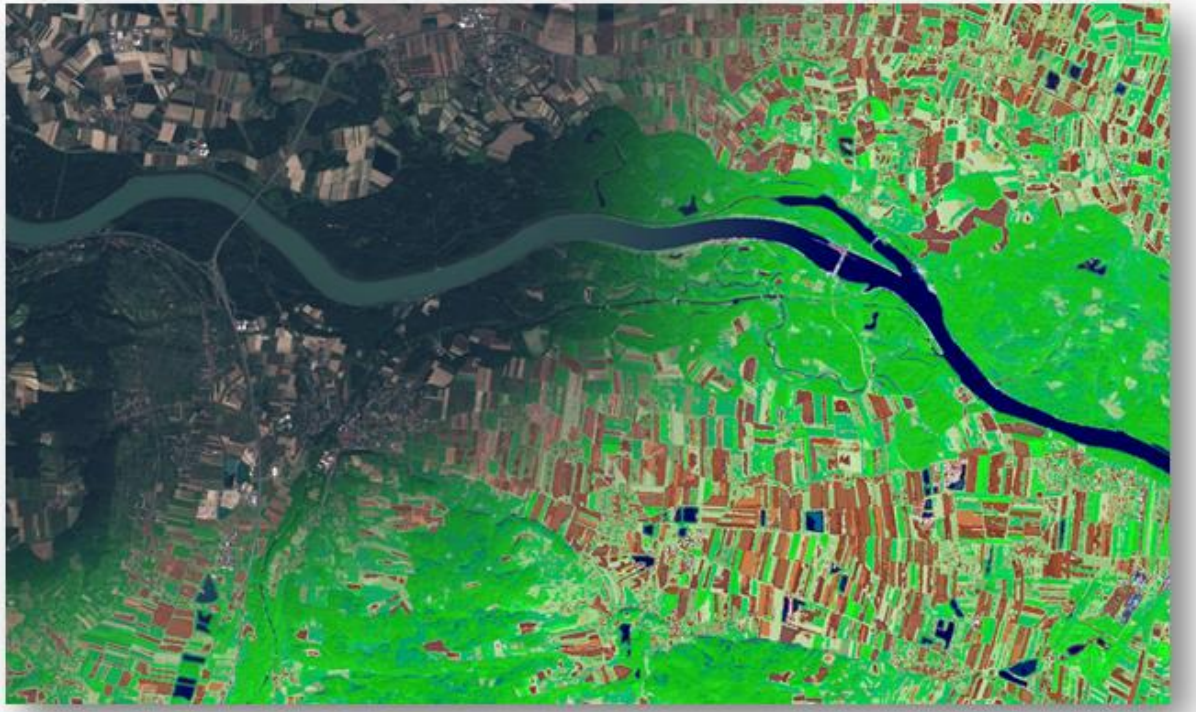
Every (optical) EO image **has a semantic skin/layer**:

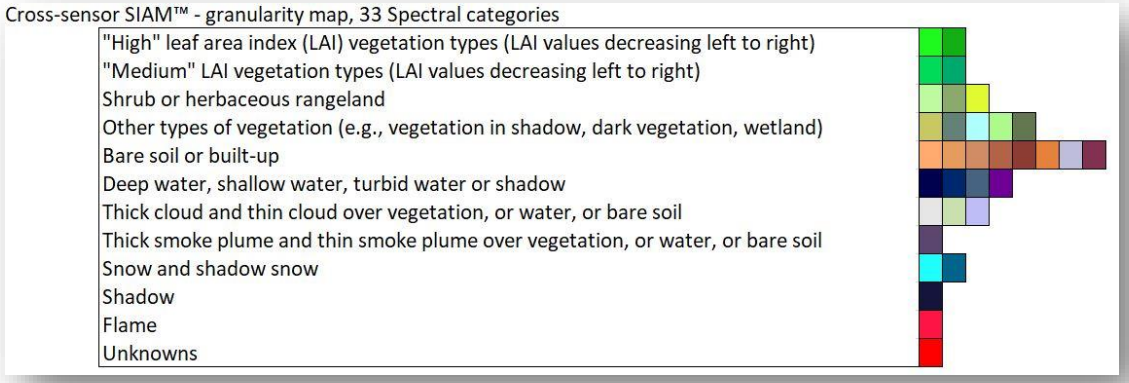
- Reflectance values are associated to **spectral categories**
- **Transferrable** between sensors
- Time series of spectral categories are the **basis for on-demand semantic queries**

① Semantic enrichment

SIAM (Satellite Image Automatic Mapper) "multi-spectral colour naming"

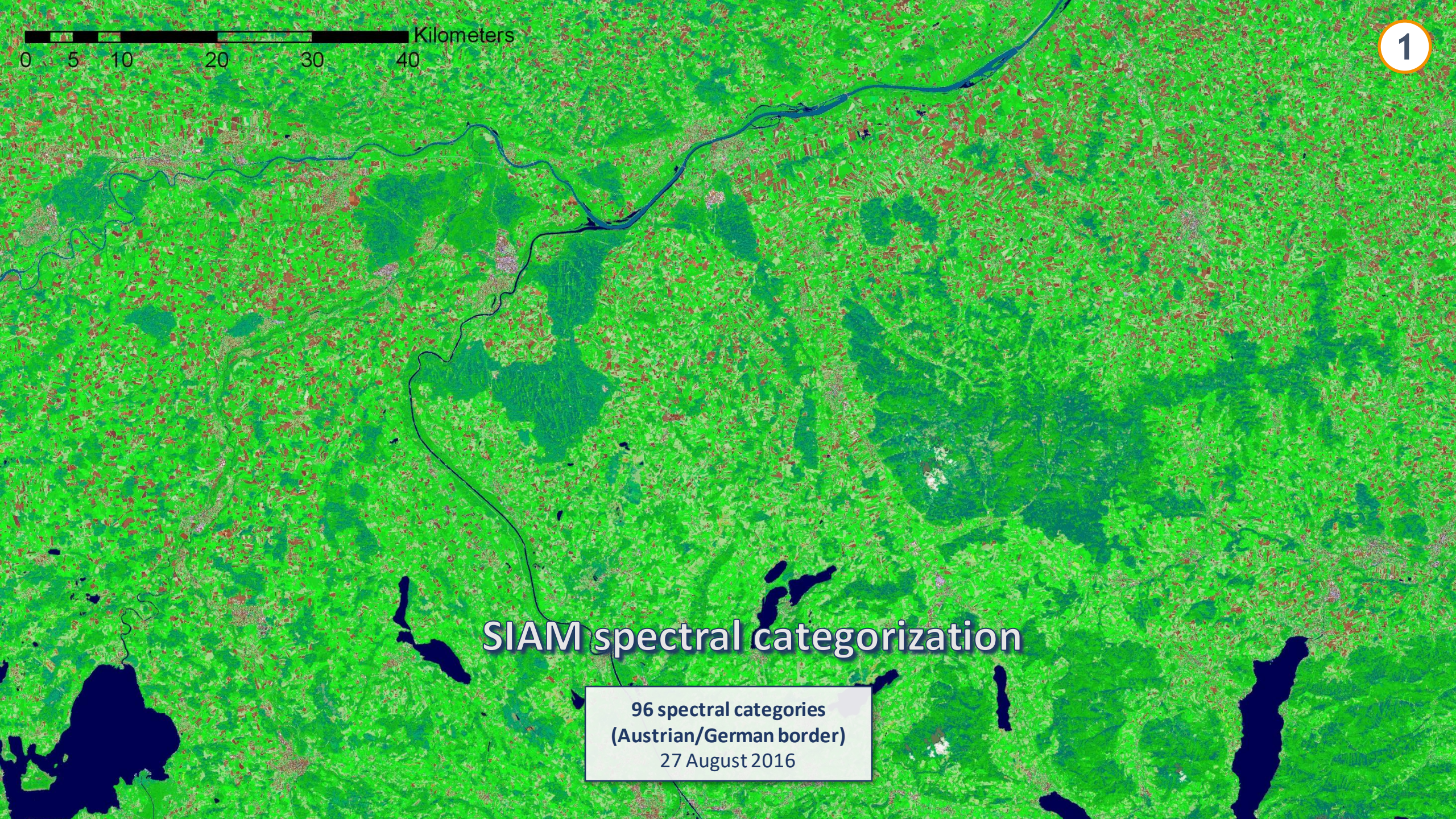
- Fully automated, based on a physical model
- **No parameter, no training-samples**
- Near real-time (< 5 min. for a Sentinel-2 granule)
- Scalable, parallelisable in Docker containers
- Multi-sensor support (at least TOA calibration)



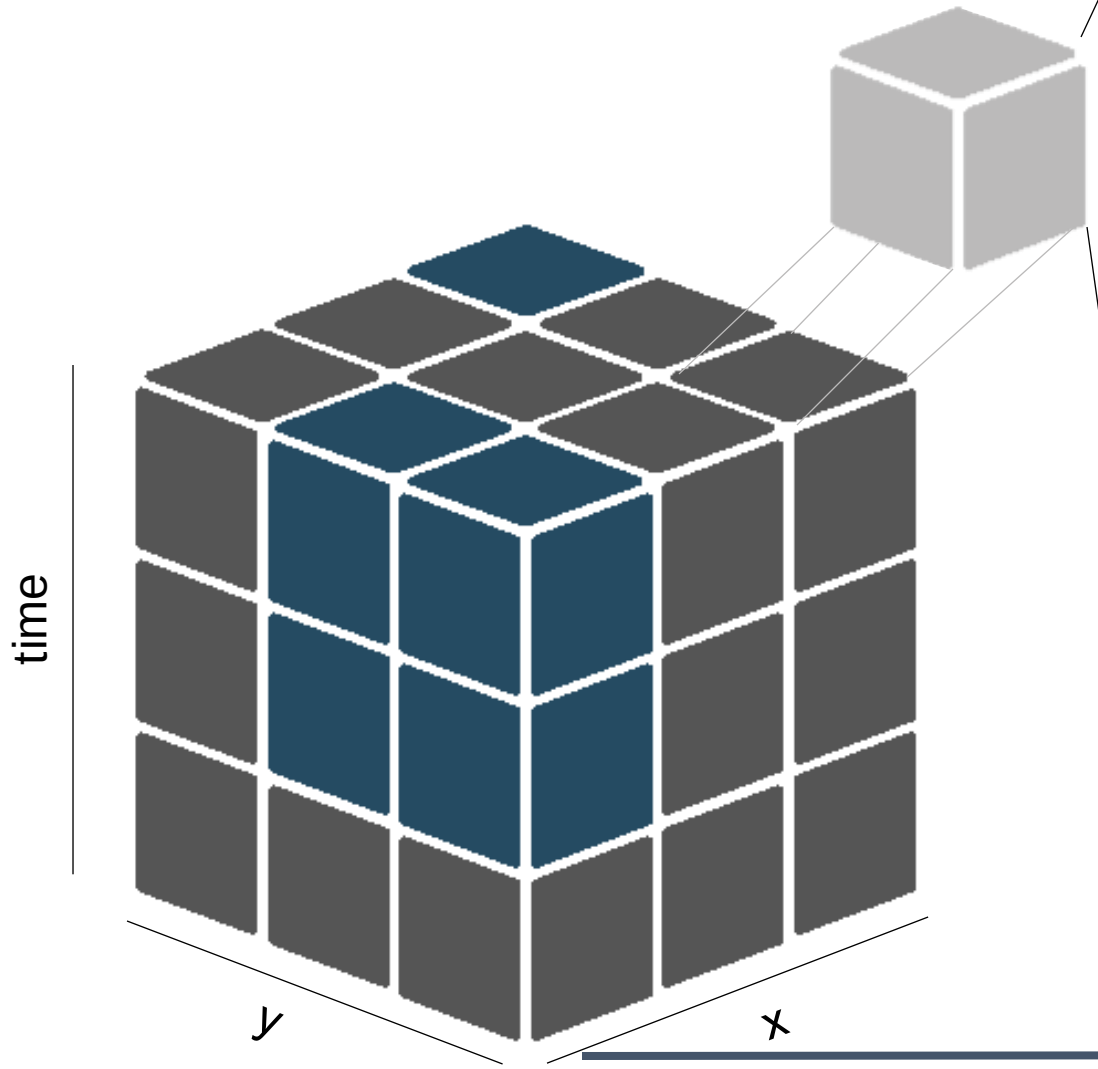


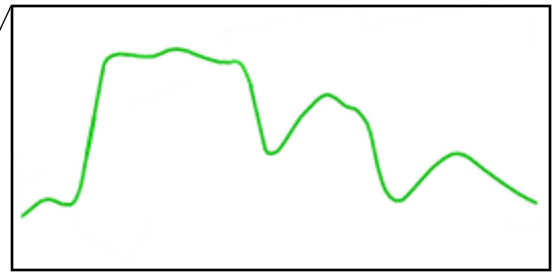
Baraldi, A., Sapia, L. D., Tiede, D., Sudmanns, M., Augustin, H. L., & Lang, S. (2022). Innovative Analysis Ready Data (ARD) product and process requirements, software system design, algorithms and implementation at the midstream as necessary-but-not-sufficient precondition of the downstream in a new notion of Space Economy 4.0 - Part 1: Problem background in Artificial General Intelligence (AGI). Big Earth Data, 1-239. https://doi.org/10.1080/20964471.2021.2017549


Kilometers
0 5 10 20 30 40
1
SIAM spectral categorization
Sentinel-2 scene
(Austrian/German border)
27 August 2016

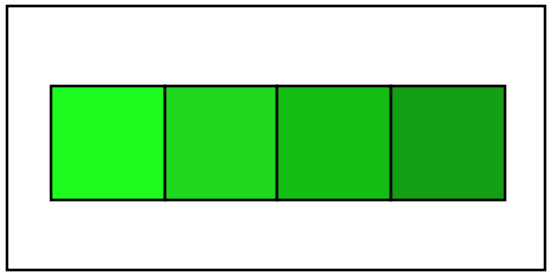

Kilometers
0 5 10 20 30 40
1
SIAM spectral categorization
96 spectral categories
(Austrian/German border)
27 August 2016

2 Data cube technology

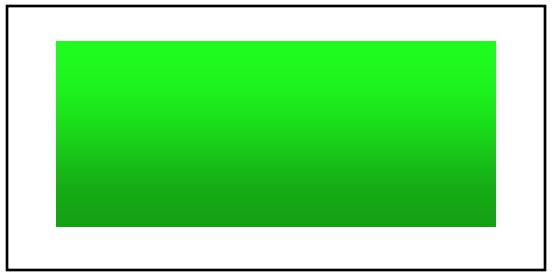




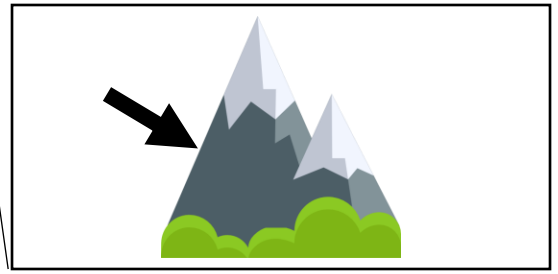
Spectral signature (reflectance)



Categorical variables

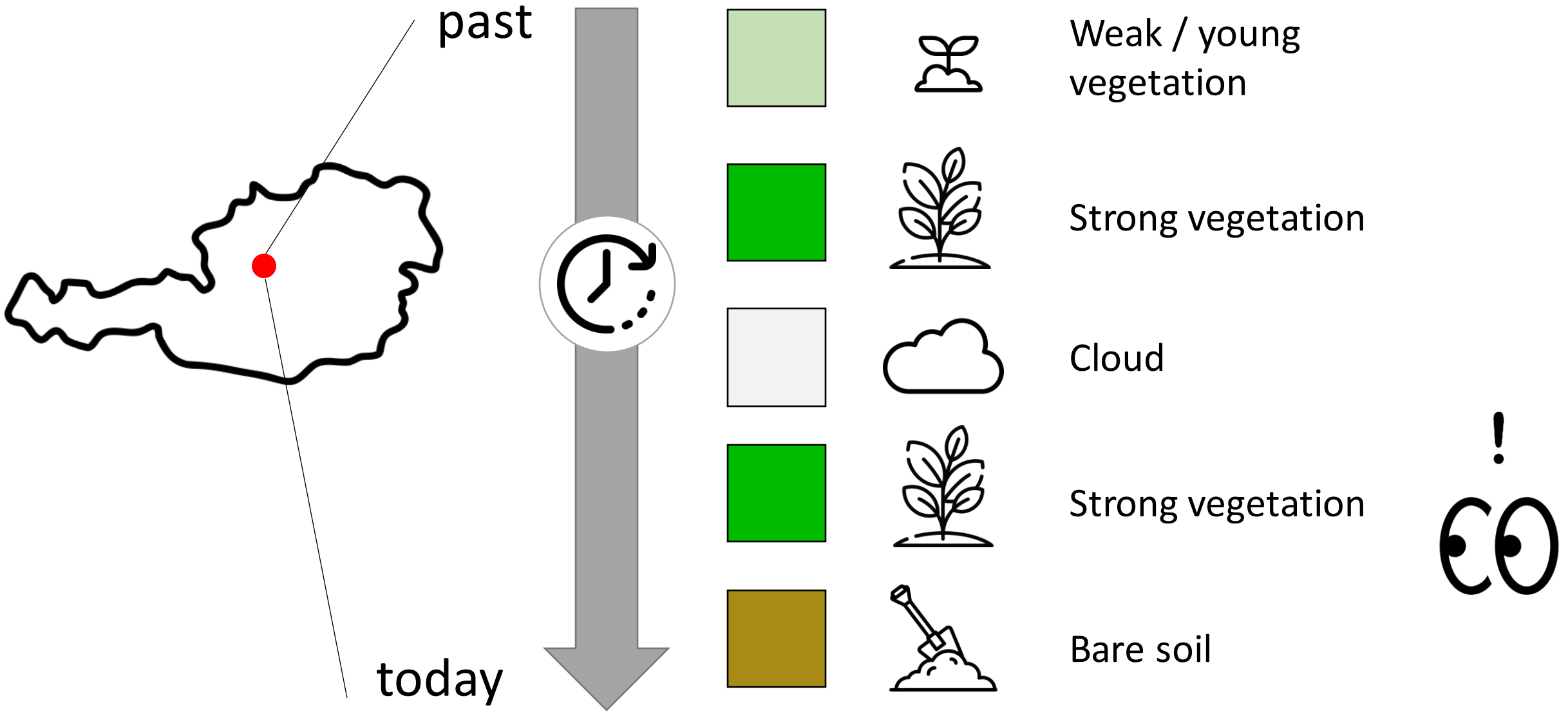


Continuous variables



Additional geograph data (e.g. altitude)

3 High-level semantic querying



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Input:

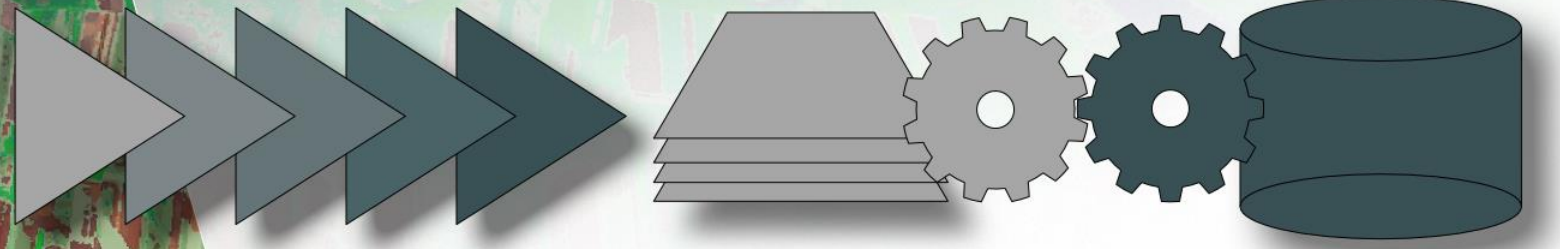
Optical EO images, at least top-of-atmosphere calibrated

Method:

Hybrid bottom-up semantic enrichment + top-down semantic querying approach

Output:

Maps, time series, ...



SCBIR

Time series analysis

Com-posites

sen2cube.at

1 Worldwide applicable **semantic enrichment** in different granularities

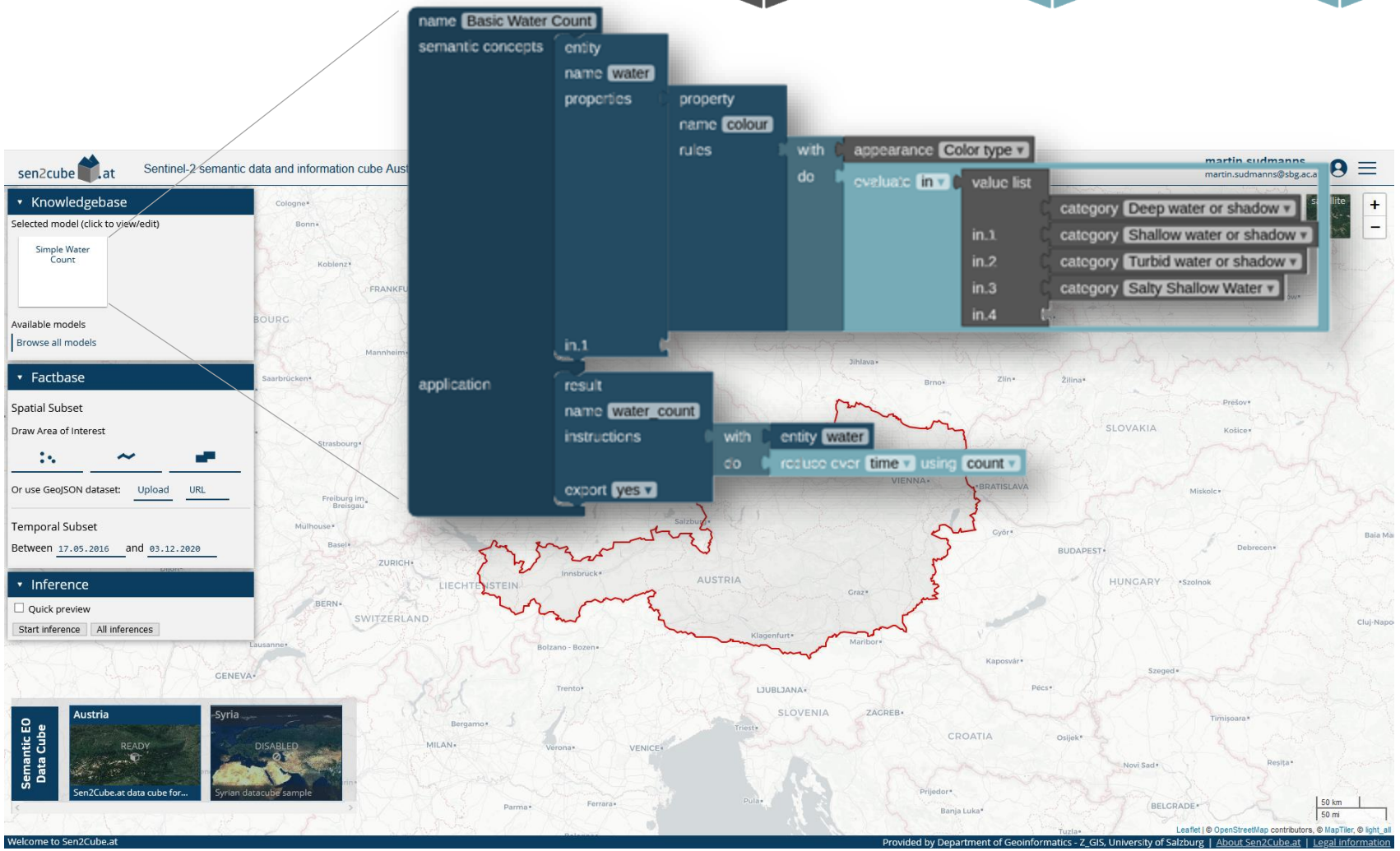
2 Application-agnostic, generic **factbase** (EO

4 Web-based **graphical inference engine** and semantic querying language

3 Shared **knowledgebase** containing semantic

3 High-level semantic querying

- An **inference engine for semantic querying** as a Web interface in a client-server solution.
- Different and multiple output types are possible and depending on the query.
- **Generic Web interface:** access to different semantic EO data cubes possible
- Create, save and share semantic queries in a **knowledgebase**
- **Open Source** code: https://github.com/zgis/semantique

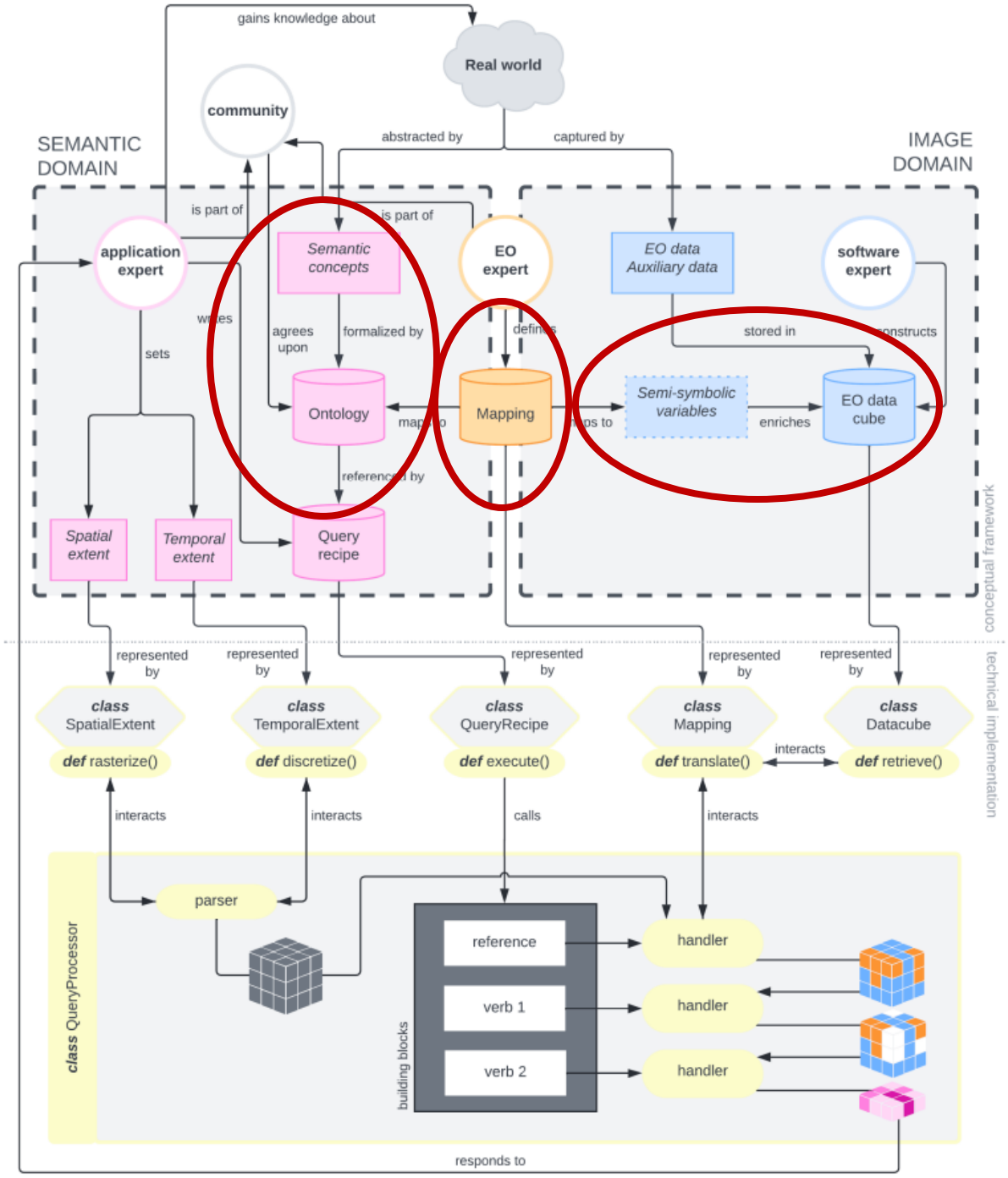


Sudmanns, M., Augustin, H., Van Der Meer, L., Werner, C., Baraldi, A., & Tiede, D. (2021). One GUI to rule them all: Accessing multiple semantic EO data cubes in one graphical user interface. GI_Forum, 9(1), 53-59. https://doi.org/10.1553/GISCIENCE2021_01_S53

Van der Meer, L., Sudmanns, M., Augustin, H., Baraldi, A., & Tiede, D. (2022). Semantic querying in Earth observation data cubes. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives, XLVIII-4/W1-2022, 503-510. https://doi.org/10.5194/isprs-archives-XLVIII-4-W1-2022-503-2022

3 High-level semantic querying

- Bridging **image domain** and **semantic domain**
- Conceptually, the two domains are separated from each other
- Implementation is Python-based and **data-cube-software agnostic** (our data cube class: OpenDataCube)



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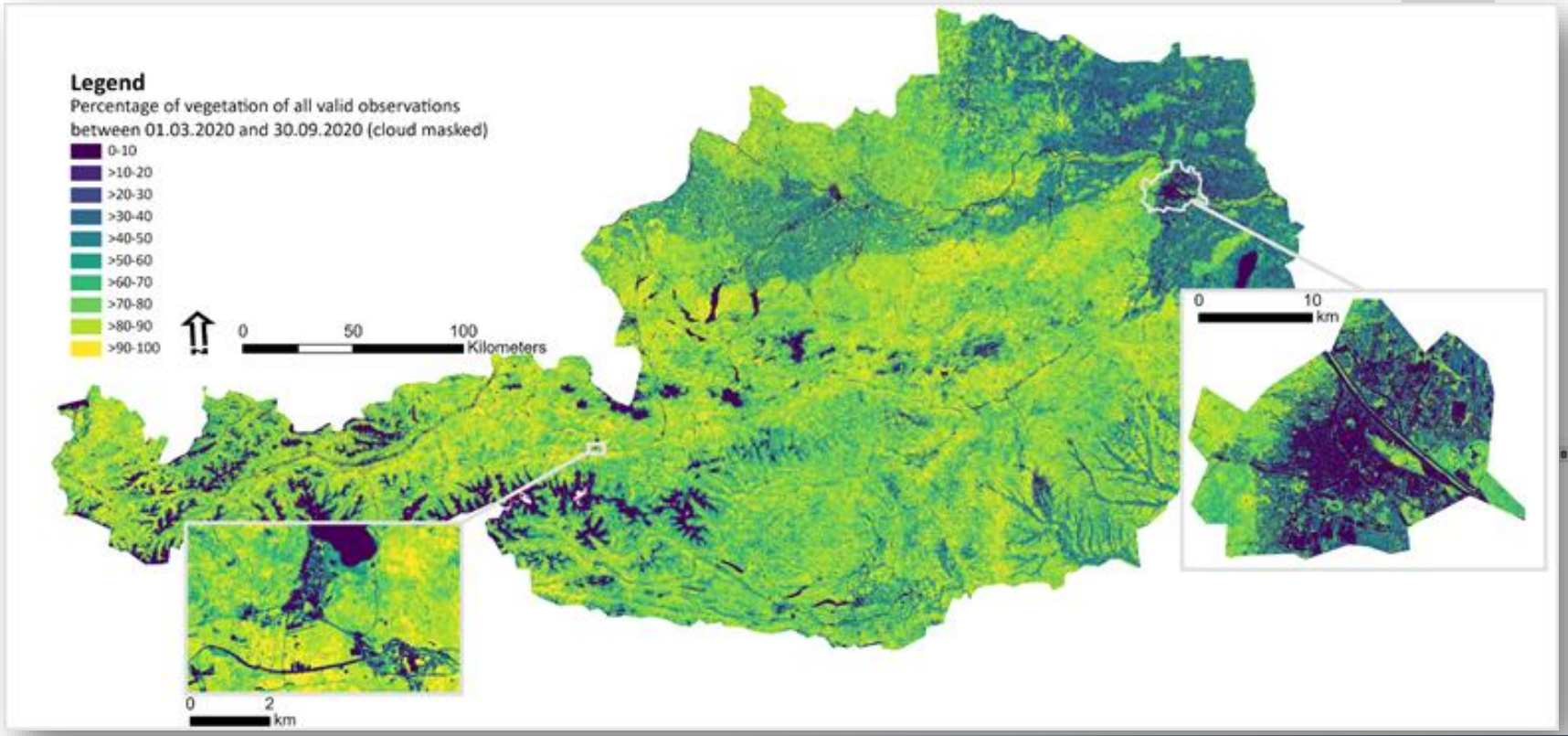
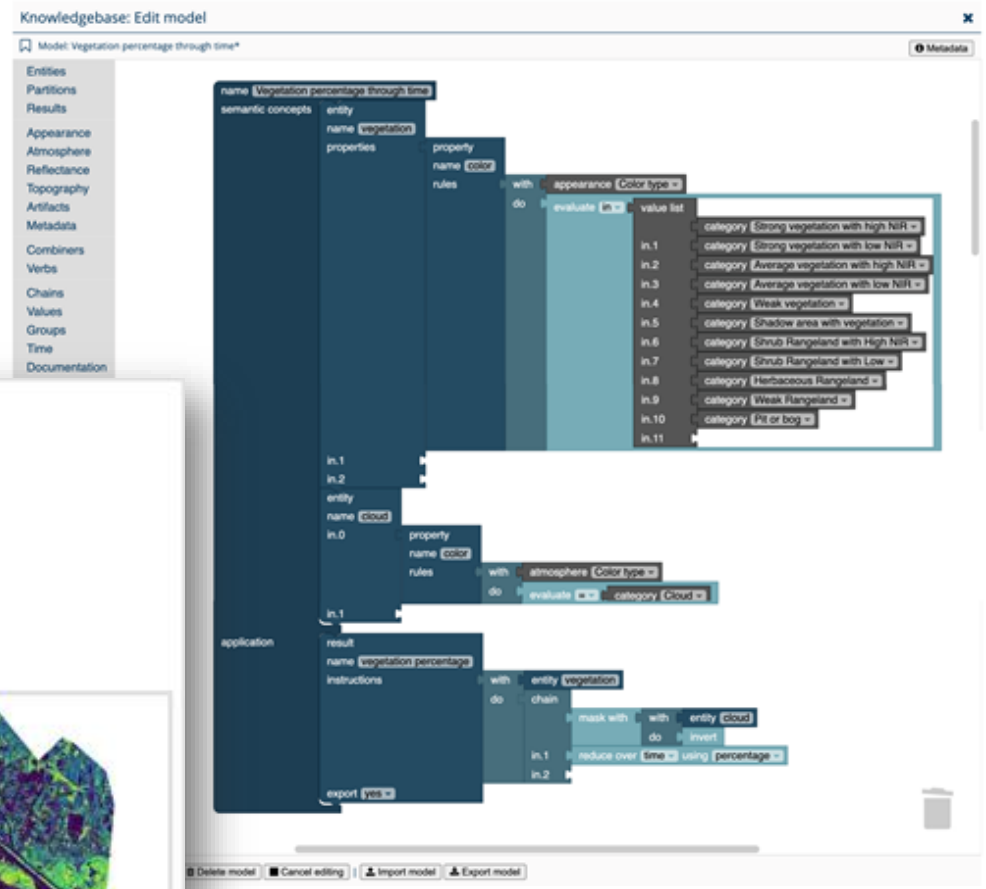
Example: How green is Austria?

National-wide information-layers

Percent of vegetation observations between March and September 2020 (without clouds) for entire Austria





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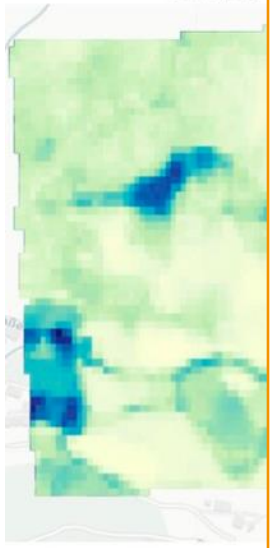
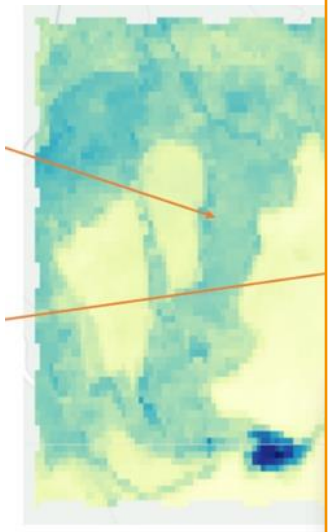
Showcasing applications

2017



May 2018



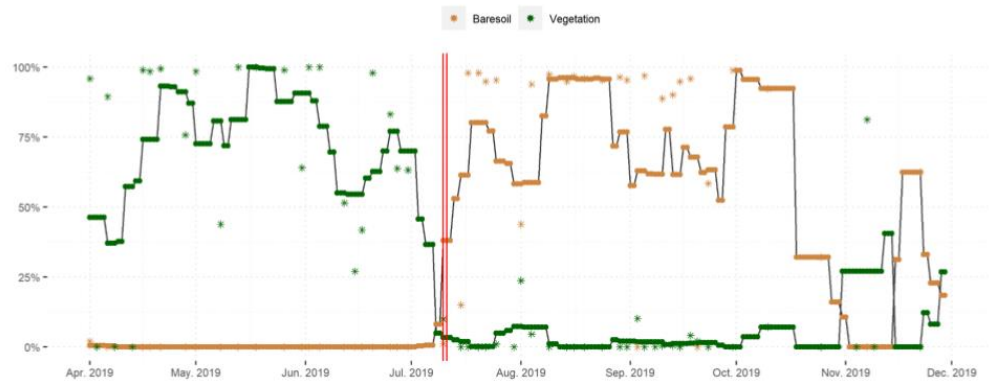
Storm damage

August 2018

2019

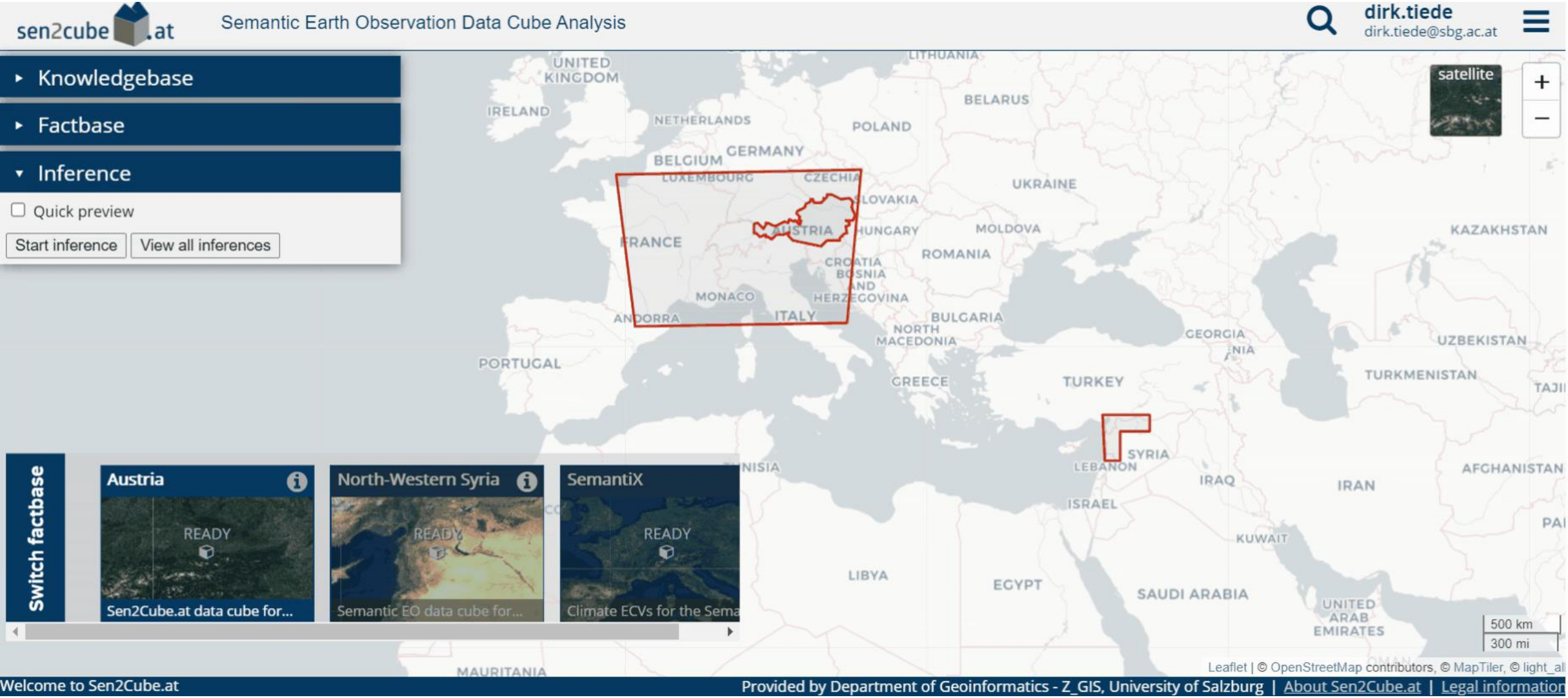
Soil Se

2020



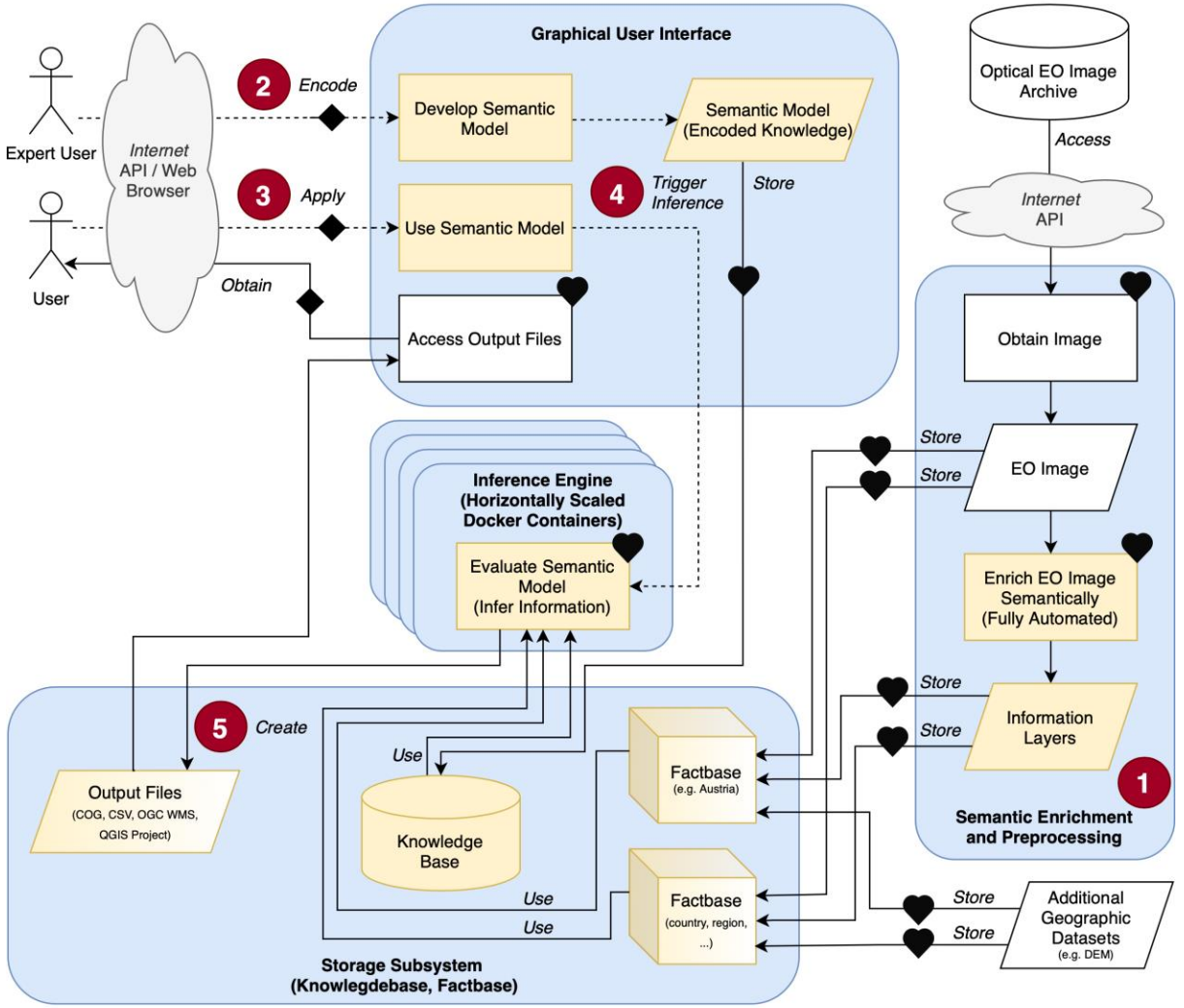
Agricultural Monitoring

Demo (Recorded)



Architecture

- scalable, **container-based** architecture
- Horizontal **scaling**
- **Concurrent multi-user** access
- A **layout** describes the semantic EO data cube's content
- multiple clients supported through an **API**



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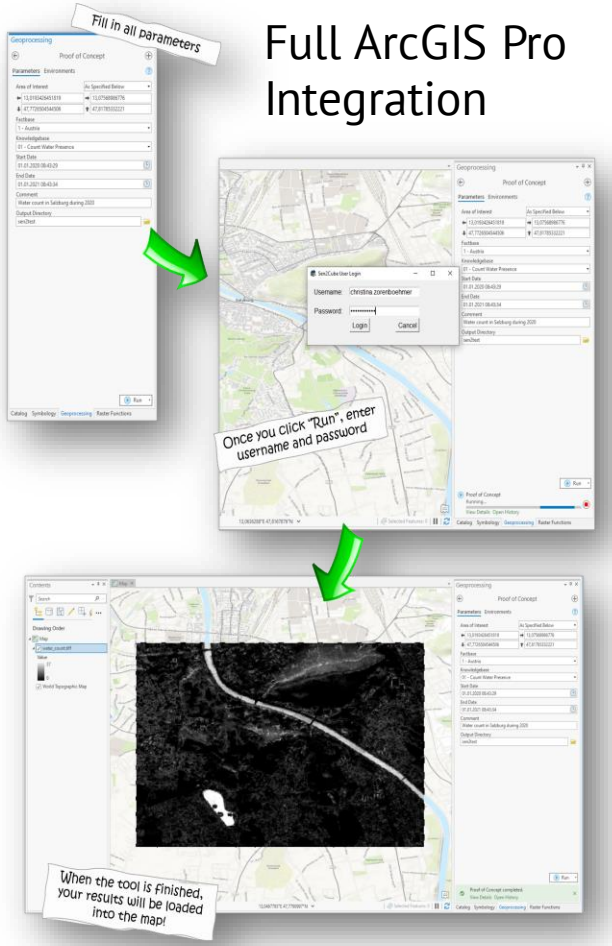
Clients and interfaces

The semantic EO data cube architecture allows:

- Executing semantic models in the cloud via standard JSON API **on-demand in the cloud**
- Earth observation data can be easily **integrated in existing software/clients**

Mobile app

Full ArcGIS Pro Integration




```
(sen2cli) sen2cli@7fa6b00b820b:~$ sen2cli --help
Usage: sen2cli [OPTIONS] COMMAND [ARGS]...

Options:
  --log_file FILE  Write log to this file instead of StdErr.
  -v, --verbose    Verbose log output. Can be added up to three times for even
                   more verbosity (WARNING, INFO, DEBUG).
  --help           Show this message and exit.

Commands:
  inference  Display / create / modify inferences
  session    Session related commands like 'login'
  version    Prints program version
(sen2cli) sen2cli@7fa6b00b820b:~$
```

Command-line interface

Nature`s Calendar citzen science app

- EO data cubes can have a significant local impact
- Adding own datasets
- Extending as midstream technology
- Make use of local knowledge and integrate communities
- Main challenge: Interoperability and transferability

Can we have a local impact?

sen2cube.at

Demo access for research possible!

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FFG Promoting Innovation.

OCRE Open Clouds for Research Environments

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